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(54) **An antenna downlink beamsteering arrangement**

Anordnung zur Antennenstrahlsteuerung der Abwärtsrichtung

Dispositif pour commander de faisceau antenne dans la liaison descendante

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(73) Proprietor: **Nortel Networks Limited**  
**Montreal, Quebec H2Y 3Y4 (CA)**

(72) Inventor: **Smith, Martin Stevens**  
**Chelmsford, Essex CM1 4XQ (GB)**

(74) Representative: **Bewley, Ewan Stuart et al**  
**Nortel Networks Intellectual Property Law Group**  
**London Road**  
**Harlow, Essex CM17 9NA (GB)**

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## Description

[0001] This invention relates to cellular radio communication systems and in particular relates to an antenna downlink beamsteering arrangement.

[0002] Cellular radio systems are currently in widespread use throughout the world providing telecommunications to mobile users. In order to meet the capacity demand, within the available frequency band allocation, cellular radio systems divide a geographic area to be covered into cells. At the centre of each cell, there is a base station through which the mobile stations communicate, each base station typically being equipped with antenna arrays arranged sectors. Configurations of three or six sectors (sub-cells) are often employed, where the higher gain of correspondingly narrower beamwidth antennas improve the uplink from the lower power mobiles. The distance between the cells is determined such that co-channel interference is maintained at a tolerable level.

[0003] Obstacles in a signal path, such as buildings in built-up areas and hills in rural areas, act as signal scatterers and can cause signalling problems. These scattered signals interact and their resultant signal at a receiving antenna is subject to deep and rapid fading and the signal envelope often follows a Rayleigh distribution over short distances, especially in heavily cluttered regions. A receiver moving through this spatially varying field experiences a fading rate which is proportional to its speed and the frequency of the transmission. Since the various components arrive from different directions, there is also a Doppler spread in the received spectrum.

[0004] When a new cellular radio system is initially deployed, operators are often interested in maximising the uplink (mobile to base station) and downlink (base station to mobile station) range. The ranges in many systems are uplink limited due to the relatively low transmitted power levels of hand portable mobile stations. Any increase in range means that fewer cells are required to cover a given geographic area, hence reducing the number of base stations and associated infrastructure costs.

[0005] The range of the link, either the uplink or the downlink, can be controlled principally in two different ways: by adjusting either the power of the transmitter or the gain at the receiver. On the downlink the most obvious way of increasing the range is to increase the power of the base station transmitter. To balance the link the range of the uplink must also be increased by an equivalent amount. The output power of a transmitter on a mobile, however, is constrained to quite a low level to meet national regulations, which vary on a country to country basis. Accordingly the receive gain at the base station must be increased.

[0006] The principal method of improving the receive system gain and to reduce the effect of fading is to include some form of diversity gain in addition to the re-

ceive antenna gain. The object of a diverse system is to provide the receiver with more than one path, with the paths being differentiated from each other by some means, e.g. space, angle, frequency or polarisation.

The use of these additional paths by the receiver provides the diversity gain. The amount of gain achieved depends upon the type of diversity, number of paths, and method of combination.

[0007] This invention is concerned with spatially diverse systems and in particular seeks to provide an arrangement wherein downlink performance is improved.

[0008] Cellular radio base stations frequently use two antennas for diversity reception on the uplink, spaced by many (e.g. 20) wavelengths. This large spacing is required because the angular spread of the incoming signals is narrow. This can be represented as a model comprising a ring of scatterers, S, around a mobile user, M, who is transmitting to a base station, B, otherwise known as the uplink path and such an arrangement is shown in Figure 1. For example the radius of scatterers may be 50 to 100 metres, and the range to the base station may be up to 10 km, resulting in a narrow angular spread. A signal transmitted from the mobile reaches the basestation having travelled via a number of paths, W, which exist as a result of scattering from obstacles randomly distributed on a circle surrounding the mobile. A large antenna spacing is required at the basestation to provide decorrelated fading, which can be calculated from the Fourier transform relationship between antenna array aperture and angular width (a large aperture in wavelengths provides a narrow beam).

[0009] In order to improve wanted signals and discriminate against interfering signals, antennas are being developed which utilise an array of antenna elements at the base station, allied with an "intelligent" beamformer. One such technique is to use a multichannel maximal ratio combiner on reception at the base station array. This operates by weighting the array signals  $s_i$  ( $i=1$  to  $N$ , where  $N$  = the number of elements in the array) with their complex conjugates  $s_i^*$  (assuming equal noise powers on each channel) and summing to give:

$$S = \sum_{i=1}^N s_i^* s_i = \sum_{i=1}^N |s_i|^2.$$

[0010] For a  $N$  element array, this provides both array gain (approximately a factor  $N$  in power) and diversity gain, the latter only if at least some of the array elements are widely spaced. Thus a factor  $N$  improvement in mean signal level can be achieved, allowing extended range or lower mobile transmit power. The array provides narrower beams than a single antenna element, and hence also provides better protection against interference, improving carrier to interference ratios and hence allowing higher capacity systems by reducing reuse factors.

[0011] The limitation of the above is that the improvements are only for the uplink, and not for the downlink (base station transmit to the mobile). The present invention seeks to provide an improved downlink signal.

[0012] A standard feature of a number of cellular radio systems is that the sets of uplink and downlink frequencies are separated into two distinct bands spaced by a guard band, for example 1800 - 1850 MHz (uplink) and 1900 - 1950 MHz (downlink). Up- and down- link frequencies are then paired off, e.g. 1800 with 1900, 1850 with 1950. There is therefore a significant change of frequency (e.g. 5%) between up and down links. There is consequently no correlation for the fast fading (as the mobile moves) between up and down links.

[0013] US-A-5260968 (Gardner et al) provides a method and apparatus for multiplexing communication signals through blind adapter spatial filtering; WO 94/09568 provides adaptive co-channel interference reduction system for cellular telephone central base stations; EP-A-0595247 provides apparatus for controlling array antenna comprising a plurality of antenna elements and method therefore; GB-A-2266998 provides a beam pattern equalisation method for an adaptive array; Personal and mobile radio communications conference, 1991, Warwick, pages 270-279, A spectrum efficient cellular base station antenna architecture was discussed by F C Swales and M A Beach, at the University of Bristol, UK. These documents do not provide improved downlink signals in non-TDD and similar systems.

[0014] The invention provides a cellular radio base station arrangement as claimed in claim 1.

[0015] Common array elements may be used for the uplink and downlink signals. Alternatively, only some of the antenna elements are employed for both the uplink and downlink signals. Separate arrays can be used for the up and down links, and in particular it may be preferable to have a closely spaced array for the downlink, with a less closely spaced array for the uplink.

[0016] In the base station arrangement, the antennas may be arranged in two groups per facet, wherein a first group comprises a plurality of antenna arrays and a second group comprises a single antenna array. Alternatively, both groups could comprise a plurality of antenna arrays.

[0017] In a further example, there is provided a method of operating the base station arrangement as claimed in claim 2.

[0018] The method of weighting the uplink signal can be performed by the use of maximal ratio combining, with the method of steering the downlink signal employing standard beam weights. Non-uniform array spacings can be used.

[0019] In order that the invention may be more fully understood, reference will now be made to the figure as shown in the accompanying drawing sheets, wherein:

Figure 1 shows a downlink signal scattering model;

Figure 2 is a graph detailing uplink and downlink gain versus antenna element spacing for a 4-element antenna array, with a mobile at broadside; and Figure 3 is a graph detailing uplink and downlink gain versus antenna element spacing for a 4-element antenna array, with a mobile at 30° from broadside.

[0020] Figure 2 shows the array gain for a four element array, where maximal ratio combining weights are used for the uplink and a standard beam (e.g. uniform amplitude array weights) are used for the downlink. The gain is shown as a function of array inter-element spacing. This figure shows gain averaged through the fast fading, and are for the case of a mobile positioned "broadside" to the array. The uplink gain rises above 6 dB (N=4) due to diversity gain (this part is dependent on the error rate). No diversity gain occurs on the downlink, as standard beam weights are used. Significant array gain is available on the downlink, provided the array spacing is not too large. It is then possible to select an array spacing such that array gain and significant diversity gain are available on the uplink, and there is still significant array gain for the downlink, for example with an array spacing of about 10 wavelengths for this scenario.

[0021] Figure 3 shows the corresponding results for the case where the mobile position is moved to 30 degrees from broadside, and direction finding (d.f.) using the uplink signals has been employed to steer the downlink beam towards the mobile and its ring of scatterers. The resulting curve is similar to the broadside case, apart from a factor to allow for the projected aperture of the array.

[0022] Two possible uplink/downlink scenarios arise from these results: Common array elements can be used with complex weights (e.g. maximal ratio combining weights) for the uplink and standard beam weights (uniform or tapered amplitude, phase slope to steer the beam) for the downlink. Alternatively, separate arrays can be used for up and down links, for example a closely spaced array can be employed for the downlink, to provide the maximum downlink gain (the left portion of the graphs in Figures 2 and 3), with a less closely spaced array being employed for the uplink, to provide maximum spatial diversity (the centre-right portions of the graphs in Figures 2 and 3). A combination of these two concepts is also possible, for example, if some elements are shared and non-uniform array spacings are used. Thus, complex array weights are employed for the uplink, the downlink beam is steered, with directional information being derived from the uplink signals.

[0023] There are various possible methods for deriving directional information from the uplink signals. One example is to use an array with a first group of closely spaced elements ( $< 1\lambda$ ), plus one or more antenna elements which are spaced from the first group of elements and can be considered as "out-lier" elements with a wide

spacing to the close spaced group, to achieve good spatial diversity gain for the uplink. The out-lier elements may comprise a single linear array or comprise a second group of elements, conveniently the same type of array as the first group whereby uniformity of componentry may be maintained and reduce costs of manufacture and ease installation.

[0024] The first group of elements (and second if of a similar configuration) can be connected to a multiple beam former, such as a Butler matrix, which forms simultaneous multiple beams spanning the sector of interest. By detecting the relative amplitudes in the multiple beams, the angle of arrival of the uplink signal can be deduced, and this information used to derive the necessary phase slope to be applied to the close spaced array elements for the downlink signal. Uplink maximal ratio combining can be performed on the complex beam outputs plus the outlier element(s) output(s).

[0025] Since direction finding is facilitated with an array containing both small and large spacings, this array configuration is also usefully incorporated for the uplink.

[0026] There are four antenna columns on a typical cellular base station facet: on the uplink all four antenna columns are used and maximal ratio combining is carried out; on the downlink, rather than combining the outputs through four transmitters, the signals are fed through one antenna. The combining advantages are lost on the downlink since the antennas of a whole array are employed for each frequency. The present invention allows the burden of combining to be shared, where there is an out-lier, whereby spatial diversity is obtained by spacing the antenna groups spaced apart. Signals do not have to be put through the transceiver transmitters of only one group of antennas of one facet: instead the signals can be split between the groups of antennas of the facet. This eases the combining load imposed on the antennas and beamformers. A further advantage lies in the reduced visual impact of a base station. Whilst there are two antenna groups per sector, which increases the number of elements liable to create a visual impact, the size of the antenna groups can be reduced whereby a smaller visual impact is created, provided that the antenna groups are sufficiently widely spaced apart.

## Claims

1. A cellular radio base station arrangement, comprising:

an antenna array comprising a plurality of antenna elements and wherein said base station arrangement further comprises means to weight received uplink signals with complex array weights and derive directional information, and means to steer downlink signals with the directional information derived from the uplink

signals; **characterised in that** said antenna elements are so spaced from one another that decorrelated fading is provided and array gain is provided such that the downlink signals are increased as compared to transmission using a single antenna element

2. A method of operating the cellular radio base station arrangement as claimed in claim 1 in order to communicate with a mobile radio said method comprising the steps of:-

- (i) receiving uplink signals from the mobile radio;
- (ii) weighting the received uplink signals with complex array weights;
- (iii) deriving directional information about the direction of the mobile radio with respect to the cellular radio base station, on the basis of the uplink signals;
- (iv) generating downlink signals; and
- (v) steering the downlink signals towards the mobile radio using the derived directional information.

3. A method according to claim 2 or an arrangement according to claim 1 wherein common array elements are used for the uplink and downlink signals.

4. A method according to claim 2 or an arrangement according to claim 1 wherein at least some common antenna elements are employed for both the uplink and downlink signals.

5. A method according to claim 2 or an arrangement according to claim 1 wherein separate antenna elements are used for the uplink and downlink signals.

6. A method or an arrangement as claimed in claim 5 wherein the antenna elements that are used for the downlink signals have a closer spacing than those antenna elements that are used for the uplink signals.

7. A method according to claim 2 or an arrangement according to claim 1 wherein the uplink signals are combined using the method of maximal ratio combining.

8. A method according to any one of claims 2 to 7 or an arrangement according to any of claims 1 or 3 to 7 wherein the downlink signals are combined using a method which employs standard beam weights.

## Patentansprüche

### 1. Zellularfunk-Basisstationsanordnung, mit:

einer Antennengruppe, die eine Vielzahl von Antennenelementen umfaßt, wobei die Basisstationsanordnung weiterhin Einrichtungen zur Bewertung empfangener Aufwärtsstrecken-Signale mit komplexen Gruppenwertigkeiten und zur Ableitung von Richtungsinformation und Einrichtungen zur Lenkung von Abwärtsstrecken-Signalen mit der aus den Aufwärtsstrecken-Signalen abgeleiteten Richtungsinformation umfaßt, **dadurch gekennzeichnet, daß** die Antennenelemente einen derartigen Abstand voneinander aufweisen, daß sich ein dekorrelierter Schwund ergibt, und daß ein Gruppen Gewinn derart geschaffen wird, daß die Abwärtsstrecken-Signale verglichen mit der Aussendung unter Verwendung eines einzigen Antennenelementes vergrößert werden.

### 2. Verfahren zum Betrieb der Zellularfunk-Basisstationsanordnung nach Anspruch 1, um mit einer Mobilfunkstation in Kommunikation zu treten, wobei das Verfahren die folgenden Schritte umfaßt:

(i) Empfang von Aufwärtsstrecken-Signalen von der Mobilfunkstation;

(ii) Bewerten der empfangenen Aufwärtsstrecken-Signale mit komplexen Gruppenwertigkeiten;

(iii) Ableiten von Richtungsinformation über die Richtung der Mobilfunkstation bezüglich der Zellularfunk-Basisstation auf der Grundlage der Aufwärtsstrecken-Signale,

(iv) Erzeugung von Abwärtsstrecken-Signalen; und

(v) Lenken der Abwärtsstrecken-Signale in Richtung auf die Mobilfunkstation unter Verwendung der abgeleiteten Richtungsinformation.

### 3. Verfahren nach Anspruch 2 oder Anordnung nach Anspruch 1, bei dem bzw. bei der gemeinsame Gruppenelemente für die Aufwärtsstrecken- und Abwärtsstrecken-Signale verwendet werden.

### 4. Verfahren nach Anspruch 2 oder Anordnung gemäß Anspruch 1, bei dem bzw. bei der zumindest einige gemeinsame Antennenelemente sowohl für die Aufwärtsstrecken- als auch die Abwärtsstrecken-Signale verwendet werden.

### 5. Verfahren nach Anspruch 2 oder Anordnung nach Anspruch 1, bei dem bzw. bei der getrennte Antennenelemente für die Aufwärtsstrecken- und Abwärtsstrecken-Signale verwendet werden.

### 6. Verfahren oder Anordnung nach Anspruch 5, bei dem bzw. bei der die Antennenelemente, die für die Abwärtsstrecken-Signale verwendet werden, einen engeren Abstand als die Antennenelemente haben, die für die Aufwärtsstrecken-Signale verwendet werden.

### 7. Verfahren nach Anspruch 2 oder Anordnung nach Anspruch 1, bei dem bzw. bei der die Aufwärtsstrecken-Signale unter Verwendung des Verfahrens einer Maximalverhältnis-Kombination kombiniert werden.

### 8. Verfahren nach einem der Ansprüche 2-7 oder Anordnung nach einem der Ansprüche 1 oder 3-7, bei dem die Abwärtsstrecken-Signale unter Verwendung eines Verfahrens kombiniert werden, das Standard-Strahlwertigkeiten verwendet.

## Revendications

### 1. Agencement de station de base radio cellulaire, comportant :

un groupement d'antennes comportant une pluralité d'éléments d'antenne et dans lequel ledit agencement de station de base comporte de plus des moyens pour pondérer des signaux de liaison montante reçus avec des poids de groupement complexes et dériver des informations directionnelles, et des moyens pour pointer des signaux de liaison descendante à l'aide des informations directionnelles dérivées des signaux de liaison montante, **caractérisé en ce que** lesdits éléments d'antenne sont espacés les uns des autres de sorte qu'un évanouissement sans corrélation est fourni et un gain de groupement est fourni de sorte que les signaux de liaison descendante sont augmentés par comparaison à une transmission utilisant un élément d'antenne unique.

### 2. Procédé pour faire fonctionner l'agencement de station de base radio cellulaire selon la revendication 1, afin de communiquer avec une radio mobile, ledit procédé comportant les étapes consistant à :

- (i) recevoir des signaux de liaison montante depuis la radio mobile,
- (ii) pondérer les signaux de liaison montante reçus à l'aide de poids de groupement complexes,

- (iii) dériver des informations directionnelles concernant la direction de la radio mobile par rapport à la station de base radio cellulaire, sur la base des signaux de liaison montante,
  - (iv) générer des signaux de liaison descendante, et 5
  - (v) pointer les signaux de liaison descendante en direction de la radio mobile en utilisant les informations directionnelles dérivées. 10
3. Procédé selon la revendication 2, ou agencement selon la revendication 1, dans lequel des éléments de groupement communs sont utilisés pour les signaux de liaison montante et de liaison descendante. 15
  4. Procédé selon la revendication 2, ou agencement selon la revendication 1, dans lequel au moins une partie des éléments d'antenne communs est utilisée à la fois pour les signaux de liaison montante et de liaison descendante. 20
  5. Procédé selon la revendication 2, ou agencement selon la revendication 1, dans lequel des éléments d'antenne séparés sont utilisés pour les signaux de liaison montante et de liaison descendante. 25
  6. Procédé ou agencement selon la revendication 5, dans lequel les éléments d'antenne qui sont utilisés pour les signaux de liaison descendante ont un espacement plus étroit que les éléments d'antenne qui sont utilisés pour les signaux de liaison montante. 30
  7. Procédé selon la revendication 2, ou agencement selon la revendication 1, dans lequel les signaux de liaison montante sont combinés en utilisant le procédé de combinaison à rapport maximal. 35
  8. Procédé selon l'une quelconque des revendications 2 à 7, ou agencement selon l'une quelconque des revendications 1 ou 3 à 7, dans lequel les signaux de liaison descendante sont combinés en utilisant un procédé qui utilise des poids de faisceau standards. 40  
45

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Fig.1.

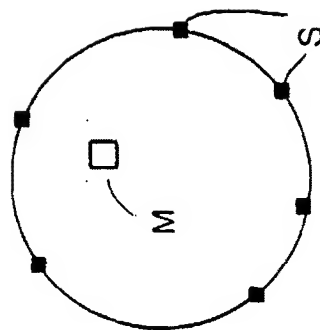
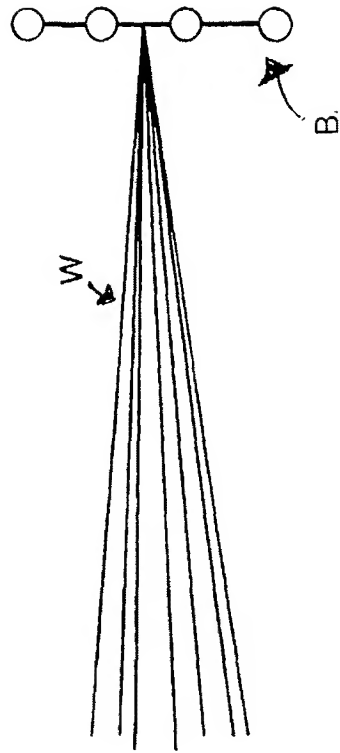


Fig.2.

RANGE=10km, 4 EVENLY SPACED ELEMENTS; MOBILE  
ON BORESIGHT; NO. OF SCATTERERS=36 AND 800 SAMPLES

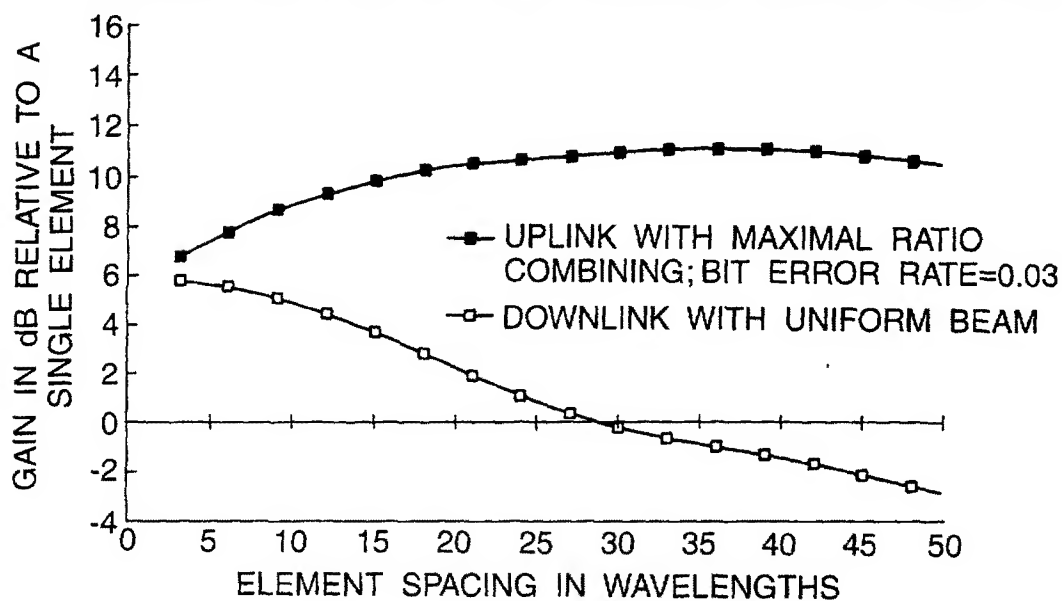


Fig.3.

10km, 4 ELEMENTS; ALPHA=30 DEGREES; NO. OF  
SCATTERERS=36 AND 800 SAMPLES TAKEN

